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FERTILIZATION OF VINE BY A 5-AMINOLEVULINIC ACID-BASED FERTILIZER AND ITS PROFITABILITY

HNOJENIE VINIČA HNOJIVOM NA BÁZE KYSELINY 5-AMINOLEVULÍNOVEJ A JEHO RENTABILITA

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ABSTRACT
In this work we investigated the effect of different doses of NPKS fertilizer added into the soil for nutrient contents in the soil, as well as the quantity and quality of grapes. During the vegetation of the vine, we tested the 5-aminolevulinic acid-based fertilizer (ALA). We summarize that higher doses of fertilizer added into soil caused higher amounts of available nutrients. During the vegetation of the vine an increase of ALA had a positive effect on the optimal balance of nutrients. Fertilization also increased the grape-vine yield, with the strongest effect (by 68%) observed due to the application of ALA during the vegetation period of the vine. Added fertilizers had a statistically significant influence on decreased sugar concentration in the grape-vine however the addition of fertilizer into the soil, mainly the application of ALA during vegetation of the vine (by 57%) had a positive effect on increase of the total content of sugar in the grape-vine, produced on 1 hectare. The year had a significant influence on the economical evaluation.

Keywords: 5-aminolevulinic acid-based fertilizer, economical effectiveness of fertilizers, fertilization, vine

ABSTRAKT
V práci bol sledovaný vplyv stupňovaných dávok NPKS živín aplikovaných do pôdy, následne bol zisťovaný obsah prístupných foriem v pôde a ich efekt na množstvo a kvalitu hrozna. Počas vegetačného obdobia viniča hroznorodého bolo na jeho úrodotvorné parametre testované hnojivo na báze kyseliny 5-aminolevulínovej (ALA). Vyššie dávky živín aplikované do pôdy mali priamy vplyv na zvýšení ich prístupných foriem v pôde. ALA pozitívne ovplyvnila vyváženosť výživového stavu viniča počas jeho vegetácie. Celkovo hnojenie sa pozitívne prejavilo na zvýšení úrody hrozna, pričom najsilnejší efekt (o 68%) bol pozorovaný vo variante s aplikovaným hnojivom na báze ALA. Na druhej strane hnojenie malo vplyv na koncentráciu cukru v hrozne. Po prepočítaný na celkový obsah cukru z plochy hektára bol jeho najvyšší obsah zaznamenaný vo variante, kde bola aplikovaná do pôdy dávka živín v 3. intenzite hnojenia spolu s ALA (o 57%) počas vegetácie viniča. Ekonomická efektívnosť hnojenia bola štatisticky významne závislá od pestovateľského ročníka.

Kľúčové slová: Kyselina 5-aminolevulínová, ekonomická efektívnosť hnojív, hnojenie, vinič

Introduction

For centuries, wine makers have been aware of the interaction between soil variation, the performance of particular cultivars or varieties and wine quality and character (White, 2009). Quality can also be related to the effects of “terroir”, a term first established for French wines (Wilson, 1998). In the “Old World” wine industry, the concept of “terroir”, is used to describe all aspects of the environment, geography, geology, and cultural practices that influence grape production. It is defined as the particular taste or character of a wine from a particular soil or region (Renouil and De Traversay, 1962). Terroir is considered extremely important in the European Union for the determination of viticulture areas (Wilson, 1998). Slovakia is divided into six viticulture areas. At present time, the European Union assigned to Slovakia 22200 hectares of vineyard. This allocation is not final and it can change depending on market demand (Hronský, 2009).

White (2009) identified the following key properties, with respect to an ideal soil for vine growth: soil depth, soil structure and water, soil strength, soil chemistry and nutrient supply and soil organism. In general, the vine is not demanding on the soil (Fecenko and Ložek, 2000), however it extracts the most nutrients from the soil. The yield and quality of vines and its annual life-cycle is influenced by the soil is chemical, physical properties and mechanical composition. Of 115 known elements, there are 16 for grapevines that are essential for normal fruit production (White, 2009). In soil, the vine can not substitute for nutrients which are in deficit therefore research have focused on the optimum and application key nutrients by fertilization. For example, research into N cycling in vineyard soils is well established due to the large amounts of potentially polluting N lost to surface and groundwater (Nendel and Kersebaum, 2004) and the effect of N on vine yield and wine quality (Spayd, et al., 1993; Des Gachons, et al., 2005). Adequate N is important not only for fruit yield, but also for maintaining an optimum N concentration in the berries for fermentation (White, 2009). Leaf and soil analysis is very important for the calculation of fertilizer doses. In dry years, the application of fertilizers to soils is very problematic due to low solubility of nutrients in soil solution. In this situation, during the growing season of the vine, the liquid fertilizers are used on leaves. Application of liquid fertilizers has significant influence on the effects and utilizations of macro-nutrients and higher quality of products (Fecenko and Ložek, 2000).

In 2006, the Department of agrochemistry and plant nutrition (SUA-Nitra) began testing a new generation of fertilizers except nutriments as well as a 5-aminolevulinic acid (ALA). ALA is a native amino acid and it is included in plants and animals as well as in people. ALA is a normal biosphere component. In higher plants 5-aminolevulinic acid (ALA) is a key precursor of many tetrapyrrole compounds, including porphyrins for chlorophyll biosynthesis (Stobart and Ameen-Bukhari, 1984). ALA improves salt tolerance in cotton seedlings through the reduction in sodium uptake (Watanabe, et al., 2004). In addition, several physiologic effects of exogenous ALA have been found to regulate plant growth and increase productivity (Hotta, et al., 1997).

The aims of this study were (i) determination of available nutrition contents in the soil and leaves of a vine, (ii) determination of quantitative and qualitative yield parameters of a vine under the application of different fertilizer doses into soil and leaves of the vine during the growing season (iii) economical evaluation of profitability of used fertilizers. We hypothesized that: (i) increasing doses of fertilizers into soil increases the contents of available nutrients in soil (ii) the application of 5-

aminolevulinic acid-based fertilizer will yield a positive effect on nutritional balance of the vine during the vegetation period (iii) applied fertilizers will have positive effects on yield parameters of vine, which will be reflected in economical effectiveness of fertilizers.

Material and methods

Experimental design and treatments

In 2006, an experiment of the application of different doses of fertilizers in a vineyard was established in the locality of Nitra-Dražovce (48°21'6.16"N; 18°3'37.33"E), which is in the Nitra winegrowing ar ea (Central Slovakia). In 2000, the vines (*Vitis vinifera* L. cv. Chardonnay) had been planted in rows (3 m x 1 m; 3300 plants.ha^{-1}) and were trained using a rheinish-hessian system. A variety of grasses were used in the inter-rows of the vines, which were sown in 2003. Annually, a biomass of grasses was formed and mowed five times. The vines were protected against the detrimental effects of diseases and pests using standard production practice. The soil type was classified according to FAO classification a Rendzin Leptosol (WRB, 2006). It contained 569 g.kg^{-1} of sand, 330 g.kg^{-1} of silt and 101 g.kg^{-1} of clay (textural classification = medium). Chemical properties prior to the experiment are shown in Table 1.

Table 1. Chemical properties of soil before experiment (2006)

Tabuľka 1. Chemické vlastnosti pôdy pred založením experimentu (2006)

Chemical properties		Depth 0-0.3 m	Depth 0.3-0.6 m
pH (in 1 mol.dm^{-3} KCl)		7.18±0.08	7.42±0.06
Organic carbon (g.kg^{-1})		17.0±1.6	9.8±2.6
Hydrolytic acidity (cmol.kg^{-1})		0.34±0.014	0.22±0.009
Sum of basic cations (cmol.kg^{-1})		49.2±0.28	49.3±0.34
Total sorptive capacity (cmol.kg^{-1})		49.46±0.28	49.48±0.34
Base saturation (%)		99.3±0.01	99.6±0.02
Total nitrogen (mg.kg^{-1})		1867±103	1666±284
Available phosphorus (mg.kg^{-1})	Mehlich III.	99±8	53±4
Available potassium (mg.kg^{-1})	Mehlich III.	262±15	114±19
Available sulphur (mg.kg^{-1})	Mehlich III.	7.4±0.03	5.6±0.05
Available calcium (mg.kg^{-1})	Mehlich III.	3450±154	4150±212
Available magnesium (mg.kg^{-1})	Mehlich III.	152±14	194±18

The area is in a temperate climate with annual average precipitations and temperatures were 550 mm and ≥ 10 °C, respectively. The average monthly precipitation and temperatures in 2008 and 2009 and their comparison with long-term averages are in Tables 2 and 3. The real doses of nutrients used in treatments are in Table 4. Used fertilizer was Duslofert Extra 14-10-20-7. Doses of NPK in 1^{-st} degree intensity for vineyards according to Fecenko and Ložek (2000) are 80-100 N kg.ha^{-1}, 35 P kg.ha^{-1} and 135 K kg.ha^{-1}. Doses of NPK in 3^{-rd} degree intensity for vineyards according to Fecenko and Ložek (2000) are 120-140 N kg.ha^{-1}, 55 P kg.ha^{-1} and 195 K kg.ha^{-1}.

Sampling and sample preparation

In 2006, soil samples for basic soil characterizations were taken before the experiment from depths of 0-0.3 m and 0.3-0.6 m. In spring 2008 and 2009, soil samples were collected from all treatments of fertilization from the same depths taken prior to the experiment. Each sampled zone included six different locations were chosen randomly. For the purpose of determining chemical properties, soil samples were mixed to average the sample and then soil samples were dried at laboratory

Table 2. Average monthly precipitation in 2008 and 2009 *(evaluation of standard monthly precipitation based on long-term averages in 1961–2001)*

Tabuľka 2. Priemerné mesačné zrážky v rokoch 2008 a 2009 *(vyhodnotenie mesačných zrážok voči dlhodobému priemeru v rokoch 1961-2001)*

Month	*Long-term average*	*2008*		*2009*	
		Precipitation in mm	*Difference*	*Precipitation in mm*	*Difference*
January	*31*	*31*	*0*	*41*	*+10*
February	*32*	*20*	*-12*	*46*	*+14*
March	*33*	*61*	*+28*	*52*	*+19*
April	*43*	*35*	*-8*	*12*	*-31*
May	*55*	*48*	*-7*	*31*	*-24*
June	*70*	*90*	*+20*	*67*	*-3*
July	*64*	*82*	*+18*	*53*	*-11*
August	*58*	*10*	*-48*	*48*	*-10*
September	*37*	*39*	*+2*	*14*	*-23*
October	*41*	*26*	*-15*	*66*	*+25*
November	*54*	*30*	*-24*	*53*	*-1*
December	*43*	*57*	*+14*	*90*	*+47*

Table 3. Average monthly temperatures in 2008 and 2009 *(evaluation of standard monthly temperatures based on long-term averages in 1961–2001)*

Tabuľka 2. Priemerné mesačné teploty v rokoch 2008 a 2009 *(vyhodnotenie mesačných teplôt voči dlhodobému priemeru v rokoch 1961-2001)*

Month	*Long-term average*	*2008*		*2009*	
		Temperature in ^oC	*Difference*	*Temperature in ^oC*	*Difference*
January	*-1.7*	*1.7*	*+3.4*	*-2.2*	*-0.5*
February	*0.5*	*2.6*	*+2.1*	*0.7*	*+0.2*
March	*4.7*	*5.6*	*+0.9*	*5.4*	*+0.7*
April	*10.1*	*11.3*	*+1.2*	*14.7*	*+4.6*
May	*14.8*	*16.3*	*+1.5*	*16.3*	*+1.5*
June	*18.3*	*20.6*	*+2.3*	*18.1*	*-0.2*
July	*19.7*	*20.6*	*+0.9*	*21.8*	*+2.1*
August	*19.2*	*20.1*	*+0.9*	*21.5*	*+2.3*
September	*15.4*	*15.0*	*-0.4*	*17.9*	*+2.5*
October	*10.1*	*11.1*	*+1*	*9.9*	*-0.2*
November	*4.9*	*6.9*	*+2*	*6.4*	*+1.5*
December	*0.5*	*2.9*	*+2.4*	*1.1*	*+0.6*

temperature and ground. In the grape berry softening phase, vine leaves were collected in all treatments of fertilization for the nutrition state control. Whole leaves over bunches of grape (blade and petiole) were taken. A total of 100 leaves were collected from each treatment of fertilization.Vine leaves were dried at a temperature of 80°C and were then grinded.

Soil and leaf analyses

The following parameters were determined in soil samples collected prior to the experiment: soil pH, sorptive characteristics of soil (hydrolytic acidity, sum of basic cations, total sorptive capacity, base saturation), total nitrogen content (Fiala, et al., 1999), as well as total carbon content (Dziadowiec and Gonet, 1999). Also determined was the availability of phosphorus, potassium, sulphur, calcium and magnesium according to Mehlich III (Mehlich, 1984). During 2008 and 2009, soil pH, total nitrogen content, available macro-nutrients (Mehlich III.) were determined from the soil samples. The contents of macro (N, P, K, Ca, Mg, S) and micro (Zn, Fe, Mn, Cu) nutrients were determined in the vine leaves (during 2008 and 2009). Total

Table 4. The doses of used fertilizers

Tabuľka 4. Dávky použitých hnojív

Treatment	Description
Control	without fertilization
NPKS (Duslofert Extra 14-10-20-7) in 1-st degree intensity for vineyards (NPKS III.) according to Fecenko and Ložek (2000). Real doses of nutrients: 100 kg.ha^{-1} N, 32 kg.ha^{-1} P, 120 kg.ha^{-1} K.	dose of nutrients is divided: 1/2 applied into soil in spring (bud burst) and 1/2 in flowering
NPKS in 3-rd degree intensity for vineyards (NPKS I.) according to Fecenko and Ložek (2000). Real doses of nutrients: 125 kg.ha^{-1} N, 50 kg.ha^{-1} P, 185 kg.ha^{-1} K.	dose of nutrients is divided: 2/3 applied into soil in spring (bud burst) and 1/3 in flowering
NPKS III. + Pentakeep G	dose of nutrients is divided: 2/3 applied into soil in spring (bud burst) and 1/3 in flowering + during the growing season of vine application of liquid fertilizer Pentakeep G on leaf (five times during vegetation) in dose 2.5 l into 2500 l H_2O per hectare

nitrogen was determined according Kjeldahl, phosphorus – colorimetrically, potassium and calcium by flame photometry and magnesium by atomic absorption spectrophotometry (Koppová, et al., 1955). We also determined the total acid and sugar contents in the grapes (Koppová, et al., 1955).

2.4. Economical evaluation

From an economical point of view, the fertilization effectiveness, profit and profitability of fertilization (Fecenko and Ložek, 2000) were calculated with using following relations:

Fertilization effectiveness (K_{EE})

$$K_{EE} = \frac{P}{N} \quad (1)$$

where P is the increase of yield (€.ha^{-1}) by fertilization and N is the increase in cost (€.ha^{-1}) of fertilization

Profit (Z)

$$Z = P - N \quad (2)$$

where P is the increase of yield (€.ha^{-1}) resulting from fertilization and N is the increased cost (€.ha^{-1}) of fertilization

Profitability of fertilization (R)

$$R = \frac{Z}{N} \cdot 100 \quad (3)$$

where Z is profit (€.ha^{-1}) and N is increase of cost (€.ha^{-1}) by fertilization

Statistical analysis

Statistical analyses were performed using Statgraphics Plus. To test for significant differences between the investigated treatments, an analysis of variance was performed. Treatment differences were considered significant at *P* values <0.05 by the Tukey test.

Results

Effect of fertilization on nutrients content in soil

In the soil, changes of soil pH and macro nutrient contents due to the application of different doses of NPKS fertilizer are showed in Table 5. From 2006 to 2009, the values of pH were not significantly changed by the addition of fertilizers. The application of different doses of NPKS fertilizer had an influence on increasing the availability of macro nutrients (N, P, K and S) in the soil under the vine. Higher doses of fertilizer (NPKS III.) added into the soil caused an increase of available nutrients (Table 5), which confirmed our hypothesis. On the other hand, a decrease in calcium and magnesium was determined in comparison to the contents before the experiment (2006) as well as in control treatment in 2009.

Effect of fertilization on nutrients content in leaves of vine

At the stage of berry softening in vine leaves, the content of macro and microelements were examined (Tables 6 and 7). In all treatments of fertilization the nitrogen content was at the optimum level. The highest contents of P, K, Ca, Mg and S were in NPKS I. In NPKS III.+Pentakeep G the content of P was in small deficit. However, in NPKS I. and in control the content of P was in optimum. The content of Mn, Cu and Fe were adequate, although the content of Zn in control and NPKS III.+Pentakeep G was in excess. In assessing the balance of nutrition on the ratio of N:K, we found a balanced nutrient status (optimal) in the treatments NPKS III. (1.82) and NPKS III.+Pentakeep G (1.72), while the other had a slight deficit in potassium. The ratio of K: Mg in all variants was optimal, and in the variant NPKS III. + Pentakeep G was most favourable. In all variants, the ratio of P:Zn showed a small surplus of zinc and phosphorus deficiency.

Yield

Year had a statistically significant influence on the yield of the grape-vine. In 2008, the yield of the grape-vine was almost doubled that from 2009 (Table 8). Fertilization (over both years) also had a positive effect on the increase of the grape-vine yield, but there statistically significant differences were observed only between the control treatment (without fertilization) and NPKS III. + Pentakeep G as well as between NPKS I. and NPKS III. + Pentakeep G. The treatment NPKS III. + Pentakeep G also significantly affected sugar concentration. The highest sugar concentration was measured in the control treatment. Added fertilizers significantly decreased sugar concentration. 10% less sugar concentration was measured in NPKS I. than in the control. We can conclude from obtained results that fertilization had a negative effect on sugar concentration in the grape-vine. However, when the sugar concentration was expressed on area basis (Table 8), the application of fertilizers into the soil and on the leaves of the vine increased the total content of sugar in produced per hectare. In NPKS III. + Pentakeep G the highest sugar production (1268 $kg.ha^{-1}$) was calculated coinciding with the highest yield. However in this fertilization treatment (NPKS III. + Pentakeep G), the highest acidic content in grape-vine was measured.

Economic evaluation for 2008

Economical evaluation of fertilization for 2008 is presented in Table 9. In 2008, increased doses of NPKS fertilizer (I. intensity by 9%, III. intensity by 33%) had increased grape-vine yield in comparison to control. At price of grape-vine 0.6,- € per kg, the profit increased by 42.17,- $€.ha^{-1}$ in NPKS I. and by 660.29,- $€.ha^{-1}$ in NPKS III. In NPKS III. + Pentakeep G, a positive economical result was achieved. The yield of the grape-vine was more than twice as high as the control treatment (5.08 $t.ha^{-1}$; NPKS III. + Pentakeep G 9.7 $t.ha^{-1}$). In NPKS III. + Pentakeep G the profit due to application of all the fertilizers was 1152.59,- $€.ha^{-1}$. Only applied Pentakeep G applied at 0.1% concentration as 2.5 l Pentakeep G in 2500 l of water per hectare increased the profit by 492.3,- $€.ha^{-1}$ in treatment NPKS III. + Pentakeep G in comparison to NPKS III.

Economic evaluation for 2009

Application of NPKS fertilizer in I. increased the yield by 0.56 $t.ha^{-1}$, which resulted in profit 102.17,- $€.ha^{-1}$ with a coefficient of economical effectiveness of 1.44. The application of NPKS fertilizer in III. increased the yield by 10% (0.34 $t.ha^{-1}$), resulting in a loss in profit -151.71,- € (Table 10). In the case of NPKS III. + Pentakeep G, an increase of grape-vine yield represented 1.13 $t.ha^{-1}$ (33%) than in the control, but it did not influence the profit. The highest cost of fertilization resulted in a loss of profit.

Discussion

Soil pH is a very important agrochemical parameter of soil fertility, which significantly influences the growth and development of plants. Optimal pH values for releasing and uptake of nutrients are near 6.5 (Fecenko and Ložek, 2000). Values of pH can be influenced by addition of organic fertilizers (Whalen, et al., 2000; Nardi, et al., 2004), as well as mineral fertilizers (Manna, et al., 2005). Applying NPKS fertilizer to the soil did not have affect the soil pH (Table 5), which confirmed the results of Saarsalmi et al. (2006). The reasons soil pH did not change from the application of fertilizer are as follows: good buffering of soil and enough calcium and magnesium contents in soil (Table 5).

In the soil, total nitrogen concentration is relatively stable because nitrogen is inbuilt to organic compositions, which are hardly decomposed. Our obtained results showed that in NPKS I. total nitrogen content increased by 14% in comparison to 2006 (before experiment) and by 9% in comparison to the control (Table 5). The highest total nitrogen content was in NPKS III. (by 24% and 14%). The total nitrogen content in soil can be influenced by the application of organic fertilizers (Dawson, et al., 2008), inorganic nitrogen fertilizers (Jagadamma, et al., 2007) and added indirect fertilizers as slug-gashfly mixture (Šimanský, et al., 2008). Application of high doses of phosphorous fertilizers can enrich its supply in soil (Fecenko and Ložek, 2000). Phosphorus mobility is very low in soils. Before the experiment (2006) the content of phosphorus in the soil was high (76 $mg.kg^{-1}$). Yearly application of 112 $kg.ha^{-1}$ of P_2O_5 increased its content by 40% in NPKS III. All the same, application of 224 $kg.ha^{-1}$ of K_2O and 78 $kg.ha^{-1}$ of S increased the contents of available potassium and sulphur in the soil in the same treatment (Table 5).

Optimum soil for vines should provide an even supply of necessary nutrients. Their excess or deficiency can be detected in soil analysis. Determining the optimal doses of nutrients in vegetation of the vine is important foliar analysis (White, 2009). In Slovakia, the criteria for evaluation of leaf analysis were given in detail (Fecenko and Ložek, 2000) and later refined (Ložek, 2010).

Year has an influence on the yield as reported by Marino et al. (2009) and confirmed in this study (Table 8). In 2008 (better climatic conditions) the yield of the grape-vine was 80% higher than in 2009. Marino et al. (2009) observed an increase in the yield of wheat by applying higher rates of nitrogen, which is consistent with our results (Table 8). In dry years, the application of fertilizers to soils proved problematic due to low solubility of nutrients in soil solution. In this situation, liquid fertilizers can be used on the leaves during the growing season of the vine (Šimanský, et al., 2009). These positive effects were confirmed mainly in climatic dry years (Šimanský, et al., 2009), but also in our obtained results (Table 8), but also on other crops such as winter wheat (Ložek, et al., 2007) or hop (Slamka, et al., 2007).

The aim of every agricultural subject is to achieve the highest effectiveness and profitability of farming therefore in 2008 and 2009 economical effectiveness of used fertilizers was evaluated (Tables 9 and 10). The coefficient of economical effectiveness for expression economy of fertilization was used following Fecenko and Ložek (2000). It expressed an increasing yield (in €) by inserting 1,- € to fertilization costs. In 2008, the highest economical effectiveness was for treatment NPKS III. + Pentakeep G and in 2009 in NPKS I. This means that the application of fertilization into soil and the application of liquid fertilizers with 5-aminolevulinic acid had a positive effect on yield, which has been reflected in a higher profit. The same results were published about the grape-vine by Juhás et al. (2007). A positive effect on economical effectiveness from added ALA on such plants as wheat (Ložek, et al., 2007), vegetables (Varga, et al., 2009) was observed as well.

Table 5. pH and macro nutrients (average of depth 0-0.6 m) in soil ($mg.kg^{-1}$)

Tabuľka 5. Pôdna reakcia a makro živiny (priemer hĺbky 0-0,6 m) v pôde ($mg.kg^{-1}$)

Treatment	pH_{KCl}	N				P	K	S	Ca	Mg
		N_t	N_{pot}	NO_3^-	NH_4^+					
Before experiment (2006)	7.30	1767	80	2.2	18.2	76	188	6.0	3800	173
Control (without fertilization, 2009)	7.14	1925	86	2.1	4.6	72	170	6.5	3650	148
NPKS I. (2009)	7.45	2013	126	1.9	4.8	79	185	8.5	3550	144
NPKS III. (2009)	7.42	2188	85	2.1	3.5	106	198	12.9	3125	135

Table 6. Average concentration of macro-nutrients in dry leaves of vine ($mg.kg^{-1}$) in 2008-2009

Tabuľka 6. Priemerný obsah makro-živín v sušine listov viniča ($mg.kg^{-1}$) v rokoch 2008-2009

Treatment	N	P	K	Ca	Mg	S
Control	15577	2051	11225	21361	3769	2849
NPKS I.	18659	2117	11475	22156	3378	3960
NPKS III.	17979	1479	9859	19474	3666	2456
NPKS III. + Pentakeep G	19419	1413	11323	20413	2826	3850

Table 7. Average concentration of micro-nutrients in dry leaves of vine ($mg.kg^{-1}$) in 2008-2009

Tabuľka 7. Priemerný obsah mikro-živín v sušine listov viniča ($mg.kg^{-1}$) v rokoch 2008-2009

Treatment	Zn	Fe	Mn	Cu
Control	70.0	122.2	43.2	17.3
NPKS I.	45.5	173.5	53.2	15.6
NPKS III.	47.0	132.6	56.9	15.2
NPKS III. + Pentakeep G	62.9	169.2	61.3	18.0

Table 8. Statistical evaluation of yield parameters of grape-vine

Tabuľka 8. Štatistické vyhodnotenie parametrov úrody viniča

	Yield ($t.ha^{-1}$)		Sugar concentration (NM^o)		Sugar content ($kg.ha^{-1}$)		Content of acids ($g.l^{-1}$)	
Year								
2008	6.19b±1.79		17.4a±1.03		1076b±313		11.4b±1.22	
2009	3.97a±0.76		18.9b±1.05		749a±113		9.2a±0.67	
Fertilization		rel. %		rel. %		rel. %		rel. %
Control	4.21a±0.98	100	19.3c±0.76	100	807a±223	100	9.8a±0.78	100
NPK I.	4.72a±1.01	112	17.3a±0.52	90	811a±185	101	10.6a±1.41	108
NPK III.	5.22ab±1.77	124	18.8b±0.94	97	968a±356	120	10.0a±0.56	102
NPK III. + Pentakeep G	7.08b±2.93	168	18.5abc±1.75	96	1268b±535	157	11.0a±1.57	112

Different letters (a, b, c) indicate that treatment means are significantly different at P<0.05 according to Tukey test

Table 9. Economical evaluation of grape-vine yield in 2008

Tabuľka 9. Ekonomické vyhodnotenie úrody hrozna v roku 2008

Treatment	Increase of yield		Costs of fertilization and application	Fertilization effectiveness	Profit	Profitability of fertilization
	$t.ha^{-1}$	$€.ha^{-1}$	$€.ha^{-1}$		$€.ha^{-1}$	%
Control	0	-	-	-	-	-
NPK I.	0.46	276	217.23+16.6=233.83	1.18	42.17	18
NPK III.	1.69	1016	339.11+16.6=355.71	2.86	660.29	186
NPK III. + Pentakeep G	4.62	2772	339.11+16.6+911.6=1619.41	1.71	1152.59	71

Used prices: 1 kg grape-vine = 0.60,- €, Price of fertilizer in NPKS I. = 217.23,- $€.ha^{-1}$,
Price of fertilizer in NPKS III. = 339.11,- $€.ha^{-1}$, Application of fertilizer = 8.30,- $€.ha^{-1}$, = 2 times = 16.60,- $€.ha^{-1}$
1 l Pentakeep G = 65,- $€.ha^{-1}$ = 2.5 l = 162.5,- $€.ha^{-1}$= 5 times = 812,- $€.ha^{-1}$,
Application of liquid fertilizer = 19.92,- $€.ha^{-1}$, = 5 times = 99.60,- $€.ha^{-1}$

Table 10. Economical evaluation of grape-vine yield in 2009

Tabuľka 10. Ekonomické vyhodnotenie úrody hrozna v roku 2009

Treatment	Increase of yield		Costs of fertilization and application	Fertilization effectiveness	Profit	Profitability of fertilization
	$t.ha^{-1}$	$€.ha^{-1}$	$€.ha^{-1}$		$€.ha^{-1}$	%
Control	0	-	-	-	-	-
NPK I.	0.56	336	217.23+16.6=233.83	1.44	102.17	44
NPK III.	0.34	204	339.11+16.6=355.71	0.57	-151.71	-43
NPK III. + Pentakeep G	1.13	678	339.11+16.6+911.6=1619.41	0.42	-941.41	-58

Used prices: 1 kg grape-vine = 0.60,- €, Price of fertilizer in NPKS I. = 217.23,- $€.ha^{-1}$,
Price of fertilizer in NPKS III. = 339.11,- $€.ha^{-1}$, Application of fertilizer = 8.30,- $€.ha^{-1}$, = 2 times = 16.60,- $€.ha^{-1}$
1 l Pentakeep G = 65,- $€.ha^{-1}$ = 2.5 l = 162.5,- $€.ha^{-1}$= 5 times = 812,- $€.ha^{-1}$
Application of liquid fertilizer = 19.92,- $€.ha^{-1}$, = 5 times = 99.60,- $€.ha^{-1}$

Conclusion

In summary higher doses of fertilizer added to the soil increased available nutrients. During vegetation of the vine the addition of 5-aminolevulinic acid-based fertilizer had a positive effect on the optimal balance of nutrients. Fertilization also had a positive effect on the increase of the grape-vine yield, with the strongest effect observed due to application of the 5-aminolevulinic acid-based fertilizer during the vegetation period of vine. Added fertilizers had a significantly decreased sugar concentration in the grape-vine however the addition of fertilizer into soil, mainly the application of 5-aminolevulinic acid-based fertilizer during vegetation of vine had a positive effect on increase of the total content of sugar in the grape-vine produced per hectare. The year had a significant influence on the economical evaluation of applied fertilizers into the soil and leaves of the vine.

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